LBNE and LArIAT from ~~LBNE~~ my personal Point of View

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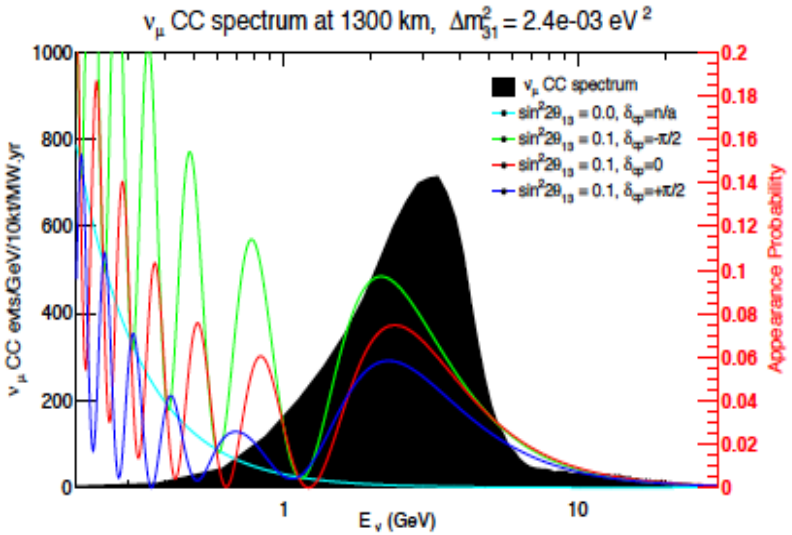
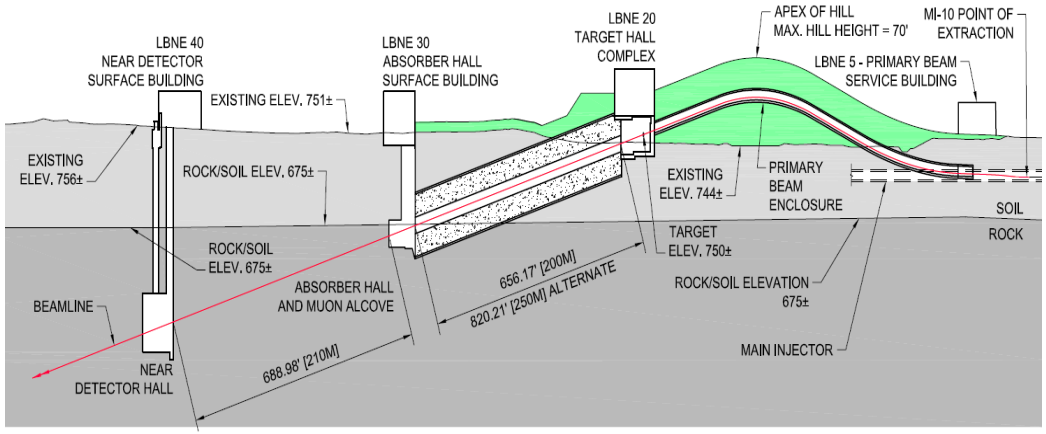
LBNE Scientific issues that require R&D and software simulation

(as summarized by M. Diwan at HEP PI meeting at Rockville MD, June 16, 2014)

1) Accelerator beam related issues

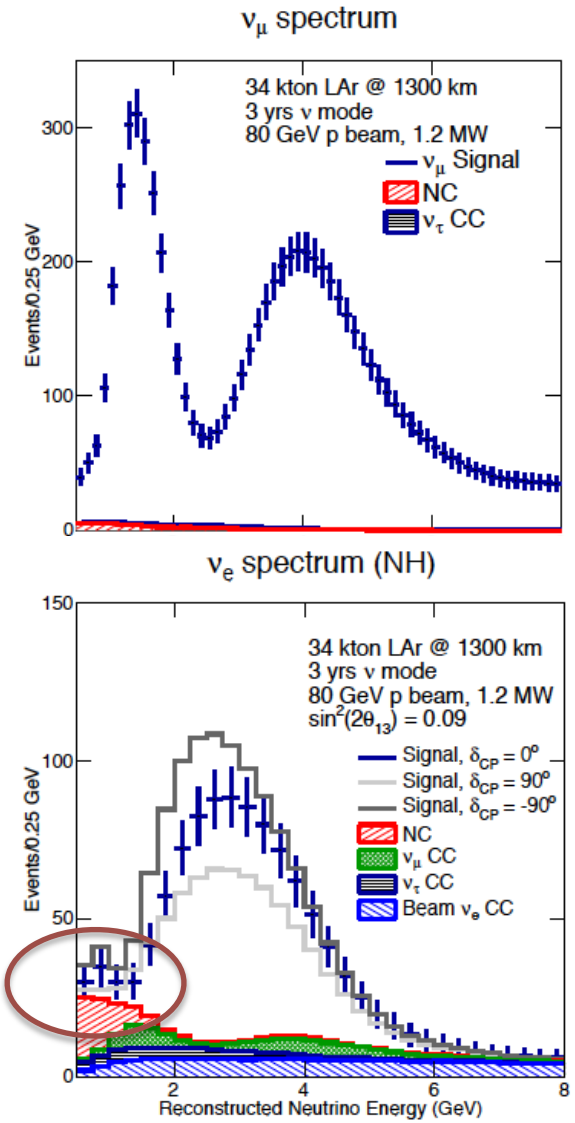




- Neutrino intensity per proton must be maximized.
- Beam must be broad-band from 0.5 GeV to 5 GeV.
- We have to understand the flux with high precision.
- There are specific ideas on how to improve the beam design by optimizing the target, horn, decay pipe, etc.

Extensive simulation and hardware R&D effort could improve the beam, particularly the flux at low energies at 2nd maximum.

2) Far and near Detector performance focus



The far detector has to be very large (34 kton) at 1300 km to obtain enough events to measure the CP asymmetry which could be <30%.

Particular attention needs to be paid to < 2 GeV for big CP effects.

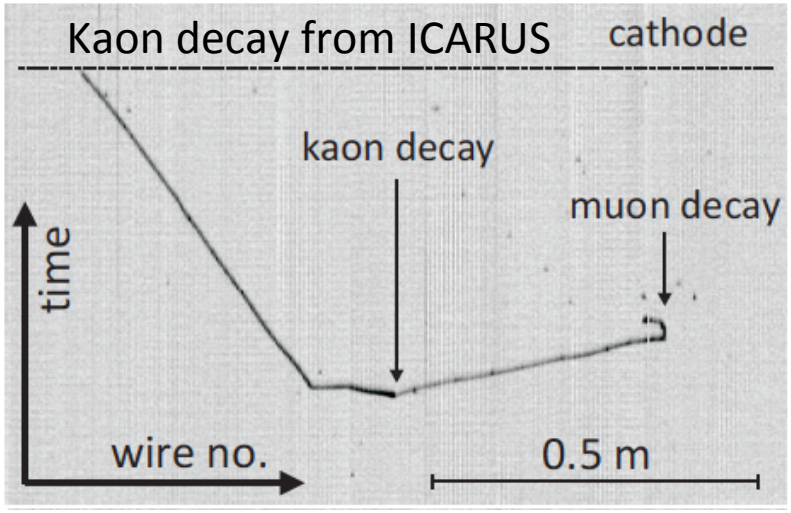
For new collaborators:

Must demonstrate efficient, high resolution, discriminating event reconstruction.

Simulate complex events with Ar nucleus and benchmark them with data.

Prototype detectors and validate designs with test beams to allow measurements with low systematic errors.

3) Other Far detector Physics

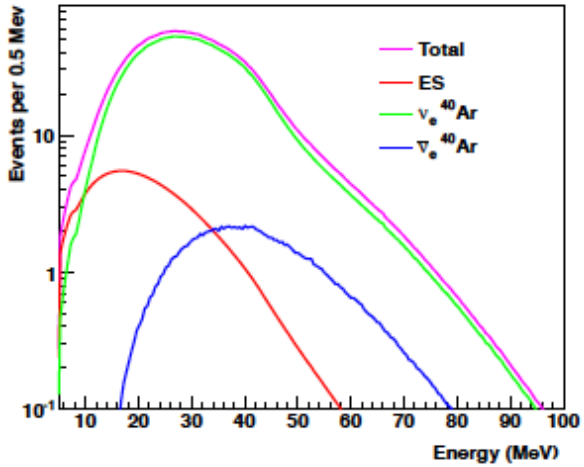


Proton decay. e.g. $p \rightarrow K^+ \bar{\nu}$

Backgrounds for proton decay: cosmic ray muons and neutrinos.

Supernova neutrinos from Milky Way.

Must have threshold and data gathering capability at <10 MeV.



Development of new readout techniques and reconstruction of low energy events could be very important.

LBNE R&D Needs

-LBNE has established R&D Coordination Committee (convenors Z. Djurcic and J. Yu) that produced a R&D briefing document (available at LBNE FNAL sharepoint page).
-Summary of Current Critical R&D Tasks Chapter

6. Summary of Current Critical R&D Tasks

A list of currently identified critical R&D tasks that could enhance the experiment is included here. This list includes dates by which the results would be needed in order for the Project to capitalize on them (i.e. before construction of the related item).

• Detector design validation studies with 35-ton prototype	2017
• Demonstration of cold digital electronics	2017
• Design of the beamline hadron monitor	2017
• Improved response of target materials to 1.2 MW proton beam	2017
• Beam muon measurement systems prototyping, simulations	2017
• Near Detector prototyping, verification of requirements, simulation	2018
• Investigation of LArTPC integrated with FGT Near Neutrino Detector	2018

Some R&D items may further improve physics performance and could come later. Conceptual work on these items should be pursued now, since they could significantly affect the integration of the rest of the components in time for the experiment to capitalize. These are listed here:

• More efficient light collection systems	2018
• Improved argon purification	2018
• Improved cryogenic liquid processing (microphonics, maintenance)	2018
• Improved understanding of HV breakdown in LAr	2018
• Detector calibration test beam measurements	2021
• Development of target and horns for improved flux spectrum	as soon as available
• Development of target and horns for 2.3 MW	> 2025

External Projects

- One of the approached to address R&D needs of LBNE is collaborating with so-called "external projects" that may be relevant to LBNE, to address the LBNE relevant R&D issues.

- These include LAr detectors that are outside of the LBNE project, including CAPTAIN, MicroBooNE, LAr1-ND, ICARUS, LArIAT and WA104 and WA105 at CERN.

- Several of these projects are proposed to be exposed to either charged particle, neutron, or neutrino beams of varying energy.

- These will provide large data sets of neutrino events in LArTPCs that will help develop reconstruction and analysis algorithms and provide detailed cross section measurements that will help LBNE make use of its FD data.

- In particular, LArIAT and WA105 propose to expose LArTPCs to charged particle test beams, providing valuable calibrations to support the analysis of LBNE data.

LBNE Physics Goals and R&D Questions

- The most important physics goal of LBNE is determination of CP-violation and measurement of δ_{CP} phase regardless its value.
  -to this end additional R&D is needed to demonstrate a high efficiency, low backgrounds, and excellent resolution for charged current electron neutrino events in the liquid argon TPC (LArTPC).

What could the test beam do:

- The LArIAT's most significant impact on LBNE would be in collecting and providing the test beam data to be used to improve understanding of the detector response and improve the detector modeling.
  - -use the data to tune/benchmark MC (Geant4)
  - -develop a full LBNE LArTPC simulation
  - -develop a reconstruction

Want this for both long-baseline and a short-baseline program!

- LArIAT could potentially deploy the readout elements constructed as close to the final LBNE design as possible.
  - -the most critical FD LArTPC R&D engineering task is a demonstration od the cold digital electronics.
  - -in a collaboration with LBNE the LArIAT could include tests of the cold digital readout for the TPC under (beginning of) development for LBNE.

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LBNE Task Force on LArIAT

- It is clear that detector calibration with test beam measurements is a critical R&D task.

- To this end LArIAT is a such test beam experiment designed to measure details of the detector response to charged particles of known energy and type. In addition it could be used as a test bed for validating engineering solutions (wire pitch, cold electronics).

- LBNE R&DCC established a task force (so-called LArIAT EPAG) to work with LArIAT and understand how LArIAT and LBNE could cooperate to understand benefits of LArIAT to LBNE:
  -what could be done when working together?
  Members: J. Stewart, B. Rebel, T. Junk, J. Urheim, A. Scaramelli

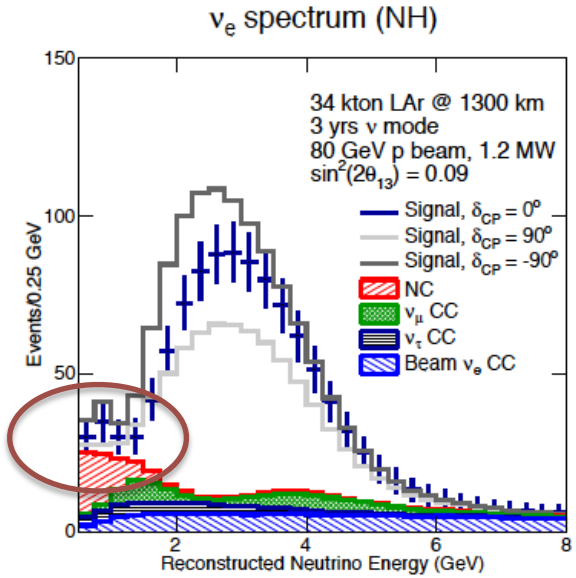
- LArIAT EPAG produced a preliminary report outlining how LArIAT could affect LBNE.
  => I assume the report is available to the members of the LArIAT Collaboration

- LBNE will need to follow up on LBNE related R&D items summarized in the report (i.e. determine who would be responsible to work with LArIAT to realize opportunities the LArIAT is offering?).

LBNE Energy Scale/Bkg Systematics

- I am personally interested to understand how LBNE physics could be enhanced, in particular through understanding energy scale systematics and improved background rejection.

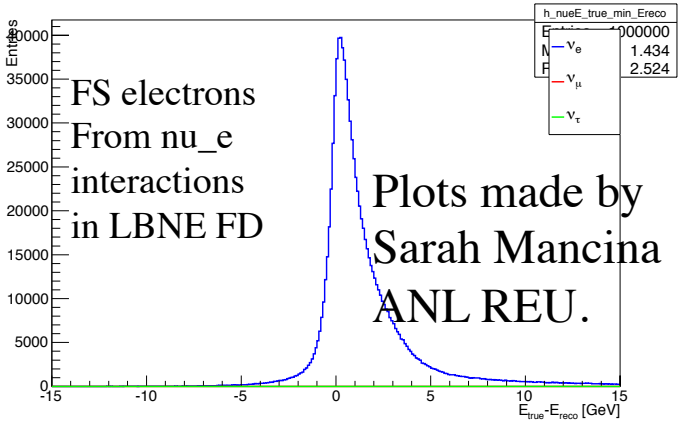
- Response of LBNE FD to EM showers in terms of energy scale and energy resolution, in particular with ν_e CC events, will determine precision on δ_{CP} measurement and mass hierarchy determination.
- ν_e CC energy will be based on components from the reconstructed electron energy, and a hadronic components of (proton) nuclear recoil.
- How well we expect to know these components (from existing expertise i.e. ICARUS, ArgoNeut)?
- How how well one needs to know electron shower energy scale? Is it same as the gamma shower (i.e. background) energy scale?



- We plan to propagate uncertainties (energy scale and resolution), through GLOBES, to learn how it affect the oscillation searches.
  It should include a variation of absolute energy scale and variations of energy resolution for both signal and backgrounds.
  -This should help planning a calibration program.

LBNE Energy Scale/Bkg Systematics

- Problem is determining what reasonable fluctuations on absolute energy scale and energy resolution are.
  Estimates currently based on detector response simulations and estimates of calibration uncertainties. => needs better understanding.
  What could we expect from test beam measurements?



- We planed to vary a bkg rate, such as NC background, and produce sensitivities to develop an idea on how a more efficient bkg rejection improves physics reach => coupled to test beam measurements.

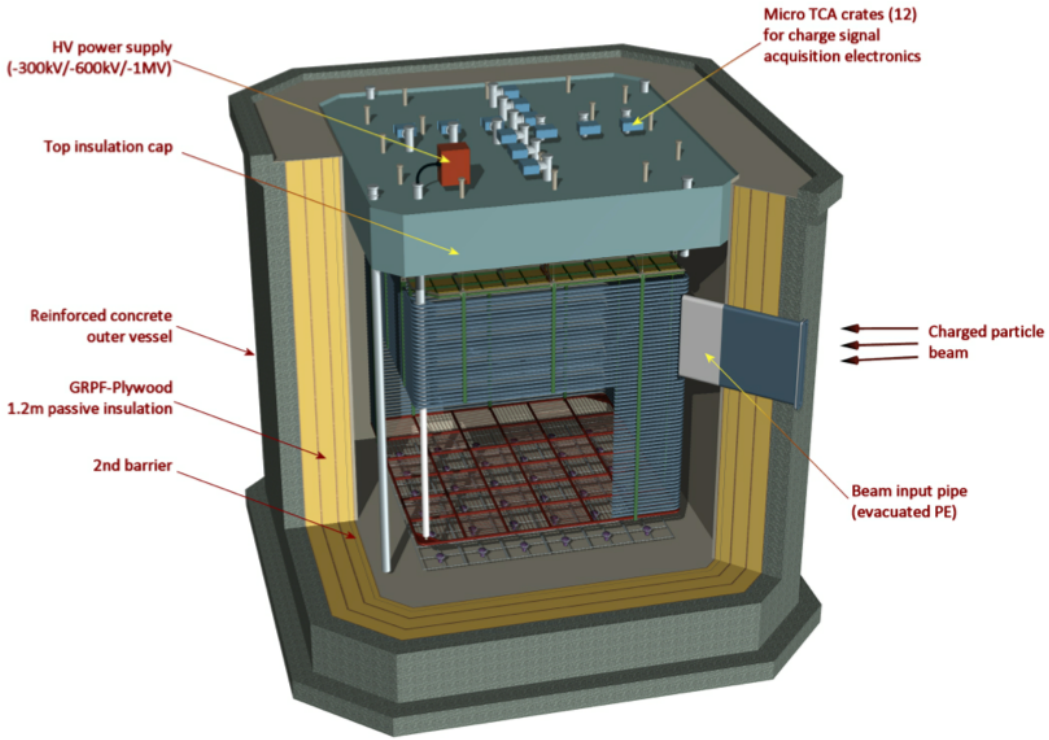
- Our knowledge of energy scale systematics, signal efficiencies, and background rejection is up to now mainly based on a hand scans of a low statistics data samples.
  => It is not clear how to move forward (without a high statistics data set and reconstruction development to perform data analysis and evaluate realistic oscillation sensitivities).

- Need a high statistics data sets to:
  -improve understanding of the LArTPC performance in reconstructing hadronic showers
  =>the most challenging part of neutrino interaction reconstruction
  -perform calorimetric measurements of electromagnetic and hadronic components
  -use data for simulation and reconstruction development and validation

- This and previous page list some of the questions that could be addressed only with test beam such as LArIAT.

WA105 (another potential test beam experiment)

-(Dual phase) LArTPC LBNO demonstrator in the test beam at CERN.



-WA105 Complementarity to LArIAT:

- Potential apples to apples comparison of dual LArTPC (LBNO baseline) to LBNE single phase LArTPC with test beam data.
- Provide further engagement of Europeans with LBNE(F) – “Internationalization” component.
- Supported by CERN.